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APPLICATION
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DIGITAL VIDEO CAMERA
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BACKGROUND OF THE INVENTION

5 The present invention relates to an edge correction apparatus for a digital video camera and, more particularly, to an edge correction apparatus for a digital video camera that can sharpen an image without degrading the image quality.

Edge correction apparatuses for conventional digital camera systems are disclosed in, e.g., Japanese Unexamined Patent Publication No. 6-14190, Japanese Unexamined Utility Model Publication No. 9-261, and "Digital Signal Processing for Single-CCD Video Camera", ITE Technical Report, Vol. 15, No. 7. Fig. 1 is a block diagram showing the arrangement of a part related to edge correction of a conventional CCD digital video camera having a general primary color Bayer layout color filter as shown in Fig. 2. Respective squares in Fig. 2 represent pixels, and letters "R", "G", and "B" mean the colors of color filters on corresponding pixels. Note that R means a red filter; G, a green filter; and B, a blue filter. Figures in some pixels are used to identify the positions of respective pixels for the following description.

In Fig. 1, an image projected on an image sensing element 101 via a lens is photoelectrically converted into a signal current within the image sensing element. The signal current is converted from an analog signal into a digital signal via an A/D converter 102, and undergoes various processes in order to obtain a normal natural image. First, the digital signal is subjected to processing of making the black level of an image uniform by an OB clamping processor 103, and then separated into R, G, and B color signals by a color separation processor 104. This color separation processing will be described. In color separation processing, arithmetic processing using convolution filters as represented by the following equations (1) to (5) is done for pixel positions on arbitrary 3 columns x 3 rows. The arithmetic operations are switched in accordance with which of R, G, and B pixel positions corresponds to a target pixel.

$$a = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix} \quad \dots(1)$$

$$b = \frac{1}{2} \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 0 \\ 0 & 1 & 0 \end{bmatrix} \quad \dots(2)$$

$$c = \frac{1}{2} \begin{bmatrix} 0 & 0 & 0 \\ 1 & 0 & 1 \\ 0 & 0 & 0 \end{bmatrix} \quad \dots(3)$$

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$$d = \frac{1}{4} \begin{bmatrix} 1 & 0 & 1 \\ 0 & 0 & 0 \\ 1 & 0 & 1 \end{bmatrix} \quad \dots (4)$$

$$e = \frac{1}{4} \begin{bmatrix} 0 & 1 & 0 \\ 1 & 0 & 1 \\ 0 & 1 & 0 \end{bmatrix} \quad \dots (5)$$

When the color of a pixel processed at given time during color signal processing is R, equations (1) to (5) yield:

R output: arithmetic result of equation (1)

G output: arithmetic result of equation (5)

B output: arithmetic result of equation (4)

When the color is G on a GR line,

10 R output: arithmetic result of equation (3)

G output: arithmetic result of equation (1)

B output: arithmetic result of equation (2)

When the color is G on a GB line,

15 R output: arithmetic result of equation (2)

G output: arithmetic result of equation (1)

B output: arithmetic result of equation (3)

When the color is B,

20 R output: arithmetic result of equation (4)

G output: arithmetic result of equation (5)

B output: arithmetic result of equation (1)

In color separation processing, an arbitrary pixel on the screen is arithmetically processed with pixels on

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Reference numeral 121 denotes an edge correction processing means. The function of this edge correction processing means 121 will be described in detail below. Processing by the edge correction processing means 121 is necessary to emphasize the sharpness of an output image

and compensate for response degradation of the optical system and image sensing device. The horizontal and vertical edge signals of an image are extracted, and multiplied by constants, respectively. The products are
5 added to the original signal to emphasize the edge component of the image, thereby increasing the sharpness.

To downsize the circuit and simplify processing, an edge signal is generated by an out-of-green method using only a green signal approximately regarded as a luminance
10 signal and green signals obtained by delaying the luminance signal by one horizontal line and two horizontal lines. For the same reason, processing by the edge correction processing means 121 is divided into horizontal edge correction processing of emphasizing and correcting
15 the horizontal edge component of an image and vertical edge correction processing of emphasizing and correcting the vertical edge component. In Fig. 1, input signals to the edge correction processing means 121 are a green signal G0 output from the color separation processor 104,
20 and green signals G1 and G2 obtained by delaying the green signal G0 by one horizontal line and two horizontal lines, respectively. An output signal from the edge correction processing means 121 is obtained as an edge correction output d, which is added by adders 122, 123, and 124 with
25 main processing signals having undergone white balance

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The respective functional blocks of the edge correction processing means 121 in Fig. 1 will be explained. In the edge correction processing means 121, a

The operations of the horizontal and vertical edge signal generators 109 and 111 as the most important processing items of edge correction processing will be explained in detail. A horizontal edge signal is generally generated by arithmetic processing between horizontally adjacent pixel components on a screen using the color-separated green signal G1. This is shown in Fig. 3. In Fig. 3, reference numerals 21 and 22 denote flip-flops (FF) for holding a pixel signal during one

5 the flip-flop 21.

2, and -1, respectively. After outputs C1, C2, and C3 from the multipliers 23, 24, and 25 are added by an adder 26, the sum is output as a horizontal edge signal a via a 1/2-level shift circuit 27. This arithmetic processing is given by the following equation. Letting G02 be a signal delayed by one pixel from the signal G01 of a given pixel on the screen, and G03 be a signal delayed by two pixels, a horizontal edge signal Gh_dt1 is given by

$$Gh_dt1 = 1/2(-G01 + 2 \times G02 - G03) \quad \dots(6)$$

20 generated by arithmetic processing between vertically adjacent pixel components in the frame using the green signals G1 and G2 obtained by delaying the green signal G0 by one horizontal period and two horizontal periods, respectively. This is shown in Fig. 4. In general, the
25 green signals G1 and G2 are simultaneously generated by

5 shows the green signals G0, G1, and G2.

G1, and G2 as

10 G0+G2: arithmetic result of equation (2)

G1: arithmetic result of equation (3)

When the color is G,

G0+G2: arithmetic result of equation (4)

G1: arithmetic result of equation (1)

15 Using these green signals G0, G1, and G2, the following arithmetic processing between pixel signals is executed. The green signals G0, G1, and G2 are respectively input to multipliers 31, 32, and 33, and multiplied by coefficients of -1, 2, and -1. After outputs C4, C5, and C6 from the
20 multipliers 31, 32, and 33 are added by an adder 34, the sum is obtained as a vertical edge signal b via a 1/2-level shift circuit 35. This arithmetic processing is given by the following equation. Letting G05 be a signal delayed by one horizontal period from the signal G04 of a
25 target pixel, and G06 be a signal delayed by two

horizontal periods, a vertical edge signal Gv_dtl is given by

$$Gv_dt1 = 1/2(-G04 + 2 \times G05 - G06) \quad \dots(7)$$

After that, the gains of the horizontal and vertical edge
5 signals are properly changed and added to attain a final
edge signal. Note that each arithmetic processing may be
done not only between three adjacent pixels, but also
between five or seven adjacent pixels to form an edge
signal.

10 Letting $G(n)$ be the output value of a green signal at
a pixel position n in a CCD digital video camera system
having a primary color Bayer layout color filter as shown
in Fig. 2, a vertical edge signal $Dtlv(5)$ at pixel
position 5 in Fig. 2 corresponding to a green color filter
15 is given from the above description and equations (1) to
(7):

$$\begin{aligned} \text{Dtlv}(5) &= G(5) - 1/2(G(2) + G(8)) \\ &= G(5) - 1/2(1/2(G(1)+G(3))+1/2(G(7)+G(9))) \\ &= G(5) - 1/4(G(1) + G(3) + G(7) + G(9)) \dots (8) \end{aligned}$$

20 This equation similarly applies to pixel positions 1, 3, 7,
9, and 11 as pixel positions corresponding to other green
color filters except that the relative positions of
corresponding pixels in equation (8) shift.

A vertical edge signal $Dtlv(8)$ at pixel position 8 in
25 Fig. 2 corresponding to a red color filter is given from

5 This equation similarly applies to pixel position 2 as a pixel position corresponding to another red color filter except that the relative position of a corresponding pixel in equation (9) shifts. Equation (8) similarly applies to pixel positions 4, 6, 10, and 12 as pixel positions
10 corresponding to other blue color filters except that the relative positions of corresponding pixels in equation (8) shift.

Fig. 5 is a view showing an example of a CCD direct output value before color separation processing when the color filter is attached to a CCD having a primary color Bayer layout. Respective squares in Fig. 5 represent pixels as in Fig. 2, and figures in these squares indicate the output values of respective pixels. In this case, the output value range is 8 bits, which are represented by an integer of 0 to 255. In Fig. 5, pixel outputs on the left side with respect to a certain vertical boundary have a minimum value of 0, and pixel outputs on the right side have a maximum value of 255. Fig. 6 is a view showing an output value when a vertical edge signal is generated from signals having values shown in Fig. 5 by processing given

by equations (8) and (9). At this time, the vertical edge signal takes a positive/negative value. For an 8-bit input signal, the signal range is 9 bits, which are represented by an integer of -256 to 255.

5 The edge correction apparatus for the conventional
CCD digital video camera operates in combination with the
color separation processor 104. When the output
difference between pixels is 0 in the vertical direction,
but the difference in output value between horizontally
10 adjacent pixels is large, as shown in Figs. 5 and 6, an
edge signal which should not exist vertically is generated
by processing given by equations (8) and (9) though the
output values of respective pixels in Fig. 6 are ideally 0.
This problem arises in another situation, in addition to
15 the case in which the output difference between pixels is
very large, as shown in Fig. 5. However, this problem
does not occur for a television signal whose three primary
colors match with each other.

SUMMARY OF THE INVENTION

20 The present invention has been made to overcome the
conventional drawbacks, and has as its object to provide
an edge correction apparatus for a digital video camera
that can suppress an unwanted vertical edge correction
signal generated when the output difference between pixels
25 is small in the vertical direction but the output

difference between horizontally adjacent pixels is large, and thus can sharpen an image without degrading the image quality.

To achieve the above object, according to the main aspect of the present invention, there is provided an edge correction apparatus for a digital video camera, comprising a horizontal edge signal generator and a vertical edge signal generator for respectively generating horizontal and vertical edge correction signals in horizontal and vertical directions of a sensed image obtained via an image sensing element of a digital video camera, a horizontal edge signal gain controller and a vertical edge signal gain controller for controlling gains of the horizontal and vertical edge correction signals respectively from the horizontal edge signal generator and the vertical edge signal generator, an adder for adding the horizontal and vertical edge correction signals whose gains are controlled by the horizontal edge signal gain controller and the vertical edge signal gain controller, a slice processor for adding, to an image processing signal of the digital video camera, an edge correction signal obtained by performing slice processing for an edge signal output from the adder, and a vertical edge component suppression position detector for causing the vertical edge signal gain controller to execute gain control of the

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vertical edge correction signal in accordance with a horizontal difference signal output from the horizontal edge signal generator.

The horizontal difference signal in the main aspect
5 includes the following signals:

(a) a signal corresponding to the luminance difference between horizontally adjacent pixels that is output from the horizontal edge signal generator;

(b) a signal corresponding to the output difference
10 in green signal between horizontally adjacent pixels that is output from the horizontal edge signal generator;

(c) a signal corresponding to the luminance difference between horizontally adjacent pixels that is output from the horizontal edge signal generator and the
15 difference between digital video camera CCD output signals vertically adjacent at the same pixel position; and

(d) a signal corresponding to the output difference in green signal between horizontally adjacent pixels that is output from the horizontal edge signal generator and
20 the difference between digital video camera CCD output signals vertically adjacent at the same pixel position

Gain control of the vertical edge correction signal by the vertical edge signal gain controller in the main aspect is executed under the following conditions:

25 (A) the amplitude of the horizontal difference signal

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exceeds a set threshold;

(B) the luminance difference between horizontally adjacent pixels is not less than a set threshold;

(C) the output difference in green signal between
5 horizontally adjacent pixels is not less than a set threshold;

(D) the luminance difference between horizontally adjacent pixels is not less than a set threshold, and the outputs of vertically adjacent digital video camera CCD
10 output signals are not more than the set threshold; and

(E) the output difference in green signal between horizontally adjacent pixels is not less than a set threshold, and the difference between vertically adjacent digital video camera CCD output signals is not more than
15 the set threshold.

As is apparent from these aspects, the present invention adopts the vertical edge component suppression position detector, and executes gain control of the vertical edge correction signal by the vertical edge
20 signal gain controller in accordance with the horizontal difference signal output from the horizontal edge signal generator. The present invention can implement an edge correction circuit which can suppress an unwanted vertical edge correction signal generated when the output
25 difference between pixels is small in the vertical

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direction but the output difference between horizontally adjacent pixels is large, and as a result, does not degrade the image quality.

The above and many other objects, features and advantages of the present invention will become manifest to those skilled in the art upon making reference to the following detailed description and accompanying drawings in which preferred embodiments incorporating the principle of the present invention are shown by way of illustrative examples.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an arrangement of a part related to edge correction of a conventional CCD digital video camera;

Fig. 2 is a view showing the color layout of a primary color Bayer layout color filter in the digital video camera shown in Fig. 1;

Fig. 3 is a block diagram showing the arrangement of a horizontal edge signal generator shown in Fig. 1;

Fig. 4 is a block diagram showing the arrangement of a vertical edge signal generator shown in Fig. 1;

Fig. 5 is an output distribution view showing the CCD direct output value of an image sensing element shown in Fig. 1;

Fig. 6 is an output distribution view showing a

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vertical edge correction output value obtained by correcting the CCD direct output value shown in Fig. 5;

Fig. 7 is a block diagram showing an arrangement of a part related to edge correction of a CCD digital video camera according to the first embodiment of the present invention;

Fig. 8 is a waveform chart showing input and output signals to and from a horizontal edge signal generator shown in Fig. 7;

Figs. 9 and 10 are graphs each showing a vertical edge signal gain control signal with respect to a horizontal difference signal shown in Fig. 7;

Figs. 11 and 12 are graphs each showing the relationship between the input and output of a vertical edge signal gain controller shown in Fig. 7;

Fig. 13 is a waveform chart showing output signals from the horizontal edge signal generator, vertical edge signal generator, and vertical edge signal gain controller shown in Fig. 7;

Fig. 14 is a block diagram showing an arrangement of a part related to edge correction of a CCD digital video camera according to the second embodiment of the present invention;

Fig. 15 is a waveform chart showing input and output signals to and from a horizontal edge signal generator

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shown in Fig. 14;

Figs. 16 and 17 are graphs each showing a vertical edge signal gain control signal with respect to a horizontal difference signal shown in Fig. 14;

5 Figs. 18 and 19 are graphs each showing the relationship between the input and output of a vertical edge signal gain controller shown in Fig. 14; and

Fig. 20 is a waveform chart showing output signals from the horizontal edge signal generator, vertical edge
10 signal generator, and vertical edge signal gain controller shown in Fig. 14.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Several preferred embodiments of the present invention will be described in detail below with reference
15 to the accompanying drawings.

sub Q' Fig. 7 is a block diagram showing an edge correction apparatus for a digital video camera according to the first embodiment of the present invention. The edge correction apparatus shown in Fig. 1 is different from the
20 conventional apparatus shown in Fig. 1 in that an edge correction processing means 121 comprises a vertical edge component suppression position detector 141. In this digital video camera, as described in "DESCRIPTION OF THE PRIOR ART", an analog video signal output from an image
25 sensing element 101 is converted into a digital signal by

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an A/D converter 102, subjected to OB clamping processing, and separated into red, blue, and green signals by a color separation processor 104. Since arithmetic processes given by equations (1) to (5) are required, color separation processing is done using an image signal having undergone OB clamping processing and image signals obtained by delaying this image signal by one horizontal line and two horizontal lines by 1H delay lines 115 and 116. This is a color separation method generally called 3-line processing. For green, green signals G1 and G2 are generated which are respectively delayed by one horizontal line and two horizontal lines so as to be used for vertical edge correction processing by a vertical edge signal generator 111. This generation method is the same as the conventional method.

In the edge correction processing means 121, a horizontal edge signal generator 109 generates a horizontal edge correction signal 149, and a horizontal difference signal 148 representing the difference in luminance or green signal between two adjacent pixels. Fig. 8 shows waveforms G1a and G1b of the signal G1 input to the horizontal edge signal generator 109, and waveforms n1 and n2 of the horizontal difference signal 148 output from the horizontal edge signal generator 109. When the waveform of an input green signal abruptly changes, like

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difference signal 148, and K1 be a coefficient used in the vertical edge component suppression position detector 141, C1 which is a vertical edge signal gain control signal 142 is generated at the suppression position of a vertical edge signal, and given as follows:

If $DS > e$,

$$C1 = K1 \cdot (n1 - e) \quad \dots(10)$$

If $DS \leq e$,

$$C1 = 0 \quad \dots(11)$$

A graph representing this relationship is shown in Fig. 9. In this case, the coefficient K1 is a constant value determined under limitations on the signal bit width of the circuit, and equations (10) and (11) exhibit linear relations. Alternatively, as shown in the graph of Fig. 10, the coefficient K1 may change depending on the magnitude of a generated unwanted vertical edge signal, and may provide a curved relationship. The threshold e can be arbitrarily set.

Letting Vdt1 be an output 150 from the vertical edge signal generator 111, Vgout be an output 152 from the vertical edge signal gain controller 112, and Ks be a coefficient used in the vertical edge signal gain controller 112, Vgout is given by

$$Vgout = Vdt1(1 - Ks \cdot K1 \cdot (n1 - e)) \quad \dots(12)$$

Fig. 11 shows the relationship between Vdt1 and Vgout when

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the coefficient K_s is constant, and $n1$ serving as the horizontal difference signal 148 is also constant. As described above, the horizontal difference signal $n1$ originally changes depending on the difference in output value between horizontally adjacent pixels. This coefficient K_s is determined under limitations on the signal bit width of the circuit. Alternatively, as shown in the graph of Fig. 12, the coefficient K_s may change depending on the magnitude of a generated unwanted vertical edge signal, and may provide a curved relationship.

This processing suppresses a vertical edge signal, as represented in Fig. 13 by the relationship between $Vdt1$ serving as the output 150 from the vertical edge signal generator 111, $n1$ serving as the horizontal difference signal 148, and $Vgout$ serving as the output 152 from the vertical edge signal gain controller 112. In Fig. 13, an output value given to each waveform is merely an example, and the output value can take various values with the same waveform.

After vertical edge signal suppression processing, the processed vertical edge signal 152 and a horizontal edge signal 151 whose gain is adjusted by the horizontal edge signal gain controller 110 are added by an adder 117. Then, the whole edge correction signal is output as an

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5 luminance signal.

25 horizontal difference signal 148 also has a flat waveform,

like the waveform m2. In Fig. 15, an output value given to each waveform is merely an example, and the output value can take various values with the same waveform.

If the amplitude exceeds a certain threshold f, like
5 the waveform m1 in Fig. 15, and the difference between three vertically adjacent CCD output signals 145, 146, and 147 having undergone OB clamping processing is equal to or smaller than a given threshold, i.e., the vertical luminance difference and vertical edge component value are
10 small around a target pixel, the vertical edge component suppression position detector 143 generates a vertical edge signal gain control signal 144, and outputs it to a vertical edge signal gain controller 112. Note that the horizontal difference signal 148 may be a signal
15 corresponding to the luminance difference between horizontally adjacent pixels that is output from the horizontal edge signal generator 109 and the difference between digital video camera CCD output signals vertically adjacent at the same pixel position, or a signal
20 corresponding to the output difference in green signal between horizontally adjacent pixels that is output from the horizontal edge signal generator 109 and the difference between digital video camera CCD output signals vertically adjacent at the same pixel position.

25 Since an unwanted vertical edge signal is generated

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at a position corresponding to the same pixel, as described in Figs. 11 and 12 and "DESCRIPTION OF THE PRIOR ART", this signal is suppressed by the vertical edge signal gain controller 112 to some degree so as not to be
5 recognized as noise on the screen. The suppression degree depends on the amplitude DS of the horizontal difference signal 148. As the amplitude exceeds the threshold f much more, the unwanted signal is suppressed more strongly. An example of this relationship is given by an equation.
10 Letting m1 be the horizontal difference signal 148, and K1 be a coefficient used in the vertical edge component suppression position detector 143, C1 serving as the vertical edge signal gain control signal 144 is generated at the suppression position of a vertical edge signal, and
15 given as follows:

If $DS > f$, and the output values of the three CCD output signals 145, 146, and 147 are equal to or smaller than a given threshold,

$$C1 = K1 \cdot (m1 - f) \quad \dots(13)$$

20 If $DS \leq f$, and the output values of the three CCD output signals 145, 146, and 147 are larger than a given threshold,

$$C1 = 0 \quad \dots(14)$$

A graph representing this relationship is shown in
25 Fig. 16, which is the same as Fig. 9 in the first

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25 depending on the magnitude of a generated unwanted

This processing suppresses a vertical edge signal, as represented in Fig. 20 by the relationship between Vdttl serving as the output 150 from the vertical edge signal generator 111, m1 serving as the horizontal difference signal 148, and Vgout serving as the output 152 from the vertical edge signal gain controller 112. In Fig. 20, an output value given to each waveform is merely an example, and the output value can take various values with the same waveform.

After vertical edge signal suppression processing,
the processed vertical edge signal 152 and a horizontal
25 edge signal 151 whose gain is adjusted by the horizontal

After vertical edge signal suppression processing,
the processed vertical edge signal 152 and a horizontal
25 edge signal 151 whose gain is adjusted by the horizontal

edge signal gain controller 110 are added by an adder 117. Then, the whole edge correction signal is output as an edge correction (processed signal) output d via a gain controller 113 and slice processor 114. Note that the
5 horizontal difference signal 148 of a green signal used in this embodiment may be used as the horizontal difference signal of a luminance signal.

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